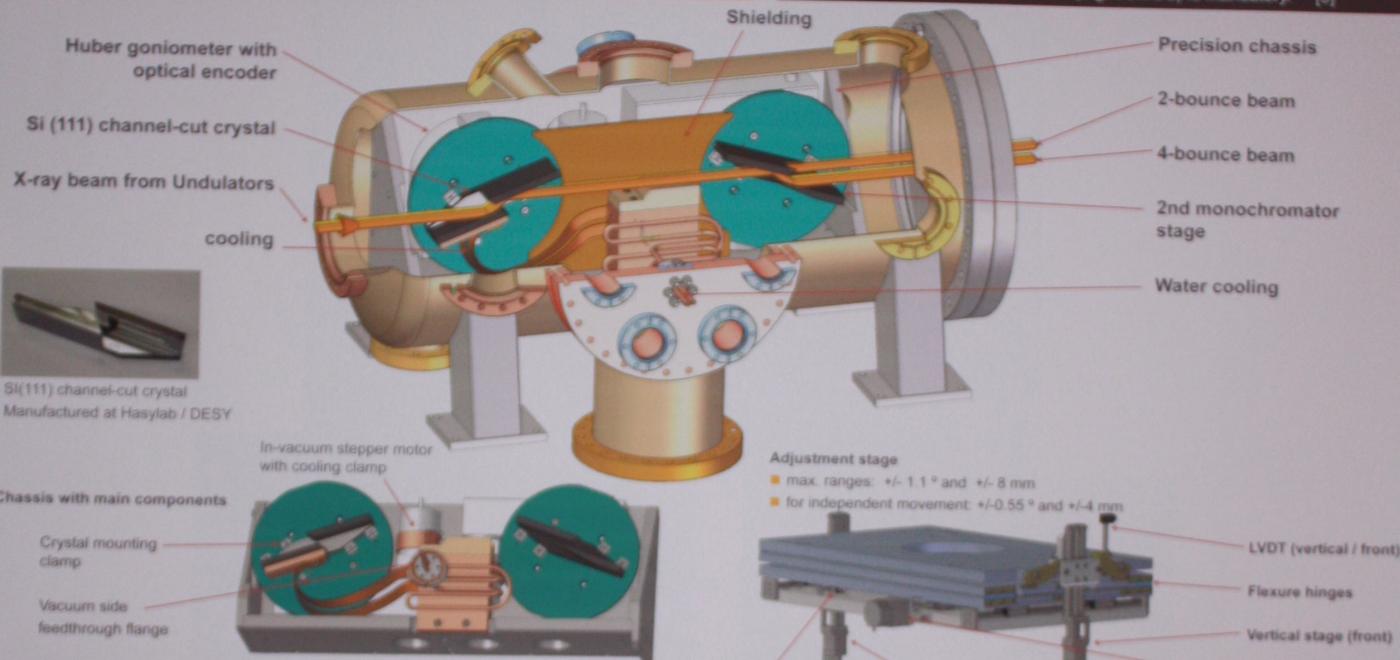


## Introduction

At the European X-ray Free Electron Laser facility (XFEL.EU) a 17.5 GeV electron beam from a superconducting linear accelerator will produce highly intense x-ray laser radiation in three up to 212 m long segmented SASE undulators. As a prerequisite to achieve lasing all 35 undulator segments must be precisely matched in their K-parameter (determined by the gap).

Three X-ray monochromators (K-Monochromator) based on Si(111) channel (cut) crystals [1] are planned for photon beam based alignment; gap tuning of the undulator segments and phase tuning of the phase shifters during commissioning and maintenance of the undulators.

A prototype device has been built using a single channel-cut crystal. It was characterized at PETRAIII synchrotron (P01: 2 undulators available) by applying different undulator adjustment methods for the XFEL.EU, which use imaging and intensity detection.



## Requirements / specifications

- Two Si (111) channel-cut crystals
- Applicable in 2-bounce or 4-bounce (Bartels) geometry
- Bragg angle range: 7° to 45°
- Energy range: 3 keV to 15 keV (9-45 keV) for Si111 (Si333)
- $\Delta E/E = 2 \times 10^{-4}$  ( $1 \times 10^{-6}$ ) for Si111 (Si333)
- Repeatability of rotary stages: better 1 μrad (0.2 arcsec)

## Mechanical setup

- Water cooling for temperature equalization and stabilization
- 2<sup>nd</sup> monochromator stage for Bartels geometry with higher energy resolution and inline geometry. It also allows slight detuning for suppression of higher harmonics (prototype: only one stage).
- Low-noise sCMOS/CCD camera with scintillation screen for imaging high or time integrated intensity (in a separate imaging station)
- Retractable diode detector for integral measurements (in imaging station)
- Huber 410D vacuum compatible goniometer stage
- Motion control with industrial Beckhoff based system
- Adjustment stage for fine height and angle adjustment

## Acknowledgments

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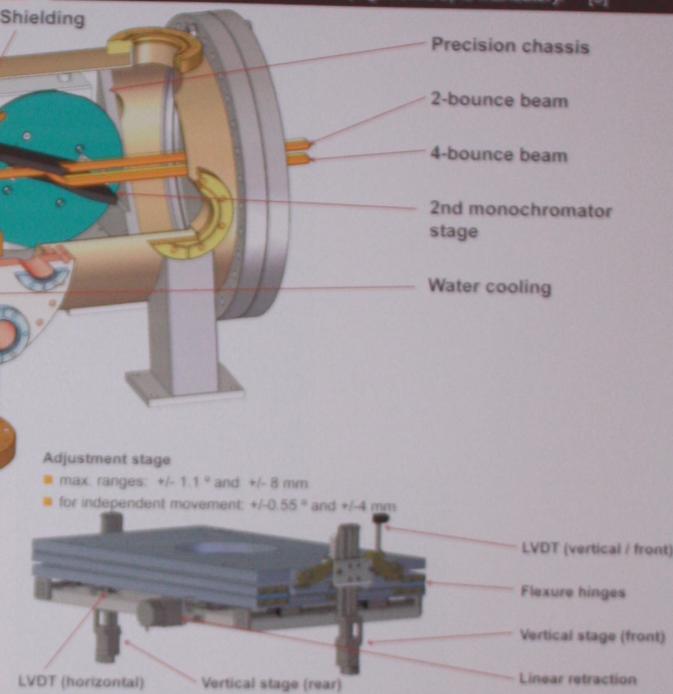
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## Determination of the undulator parameter K

Methods for K/gap determination considered:

- Gap tuning: energy spectrum of one undulator segment is measured (by switching off the others), to find its gap setting. Alternatively the gap can be varied at a fixed observation energy for maximizing the intensity [2].
- Imaging: extract the K value from the spatial distribution of the undulator radiation, slightly below the undulator resonance.
- Quadrupole kick method: the radiation of two adjacent undulator segments is examined. Between the segments a quadrupole kick deflects the electron beam by up to 20 μrad. So the intensity profiles of the two segments are spatially separated and can be directly compared. When observing the two spatially separated cones of radiation produced by the same single electron bunch, the energy jitter effect disappears. Due to the low intensity a sensitive detector (e.g. sCMOS) is mandatory. [5]



## Test setup at P01 / PETRA III (DESY)

- Single monochromator stage
- High heat-load monochromator
- Height adjustment +/- 8 mm (angle = 0 °)
- Test in He atmosphere

Imager test setup (sCMOS camera / diode)

Beckhoff based control unit



## K-value determination

Gap-field measurements of the Undulators [6]

$$E_{\text{gap}} [\text{keV}] = 0.950 \left( \frac{E_{\text{gap}}^2 [\text{GeV}]}{1 + \frac{K^2}{2}} \right) \lambda_0 [\text{cm}]$$

$$\frac{\Delta E}{E} = \left( \frac{K^2}{1 + \frac{K^2}{2}} \right) \frac{\Delta K}{K}$$

